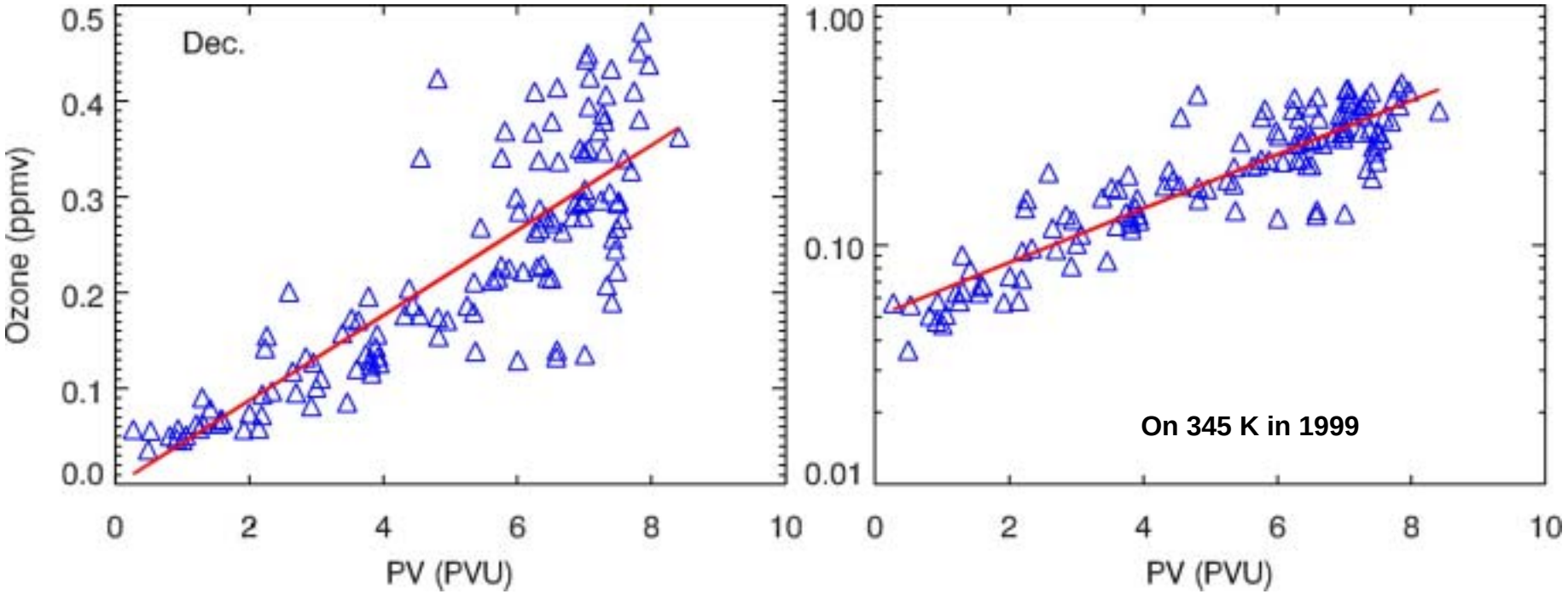
Isentropic Cross-tropopause Ozone Transport in the NH

P. Jing, D. M. Cunnold, H.-J. Wang, and E.-S. Yang

School of Earth and Atmospheric Sciences
Georgia Institute of Technology

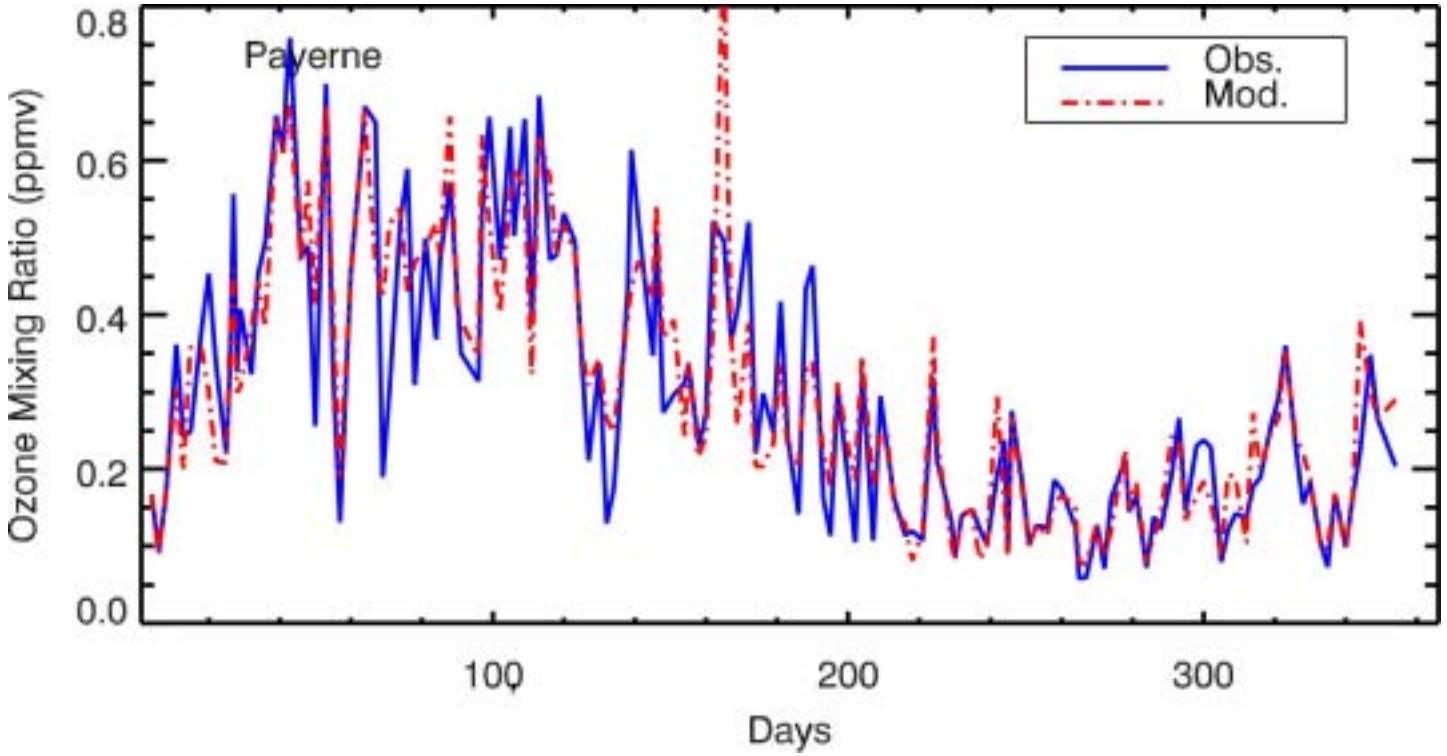
Monthly PV-O_3 relationship



O_3 = 0.0445PV - 0.0015
R = 0.84

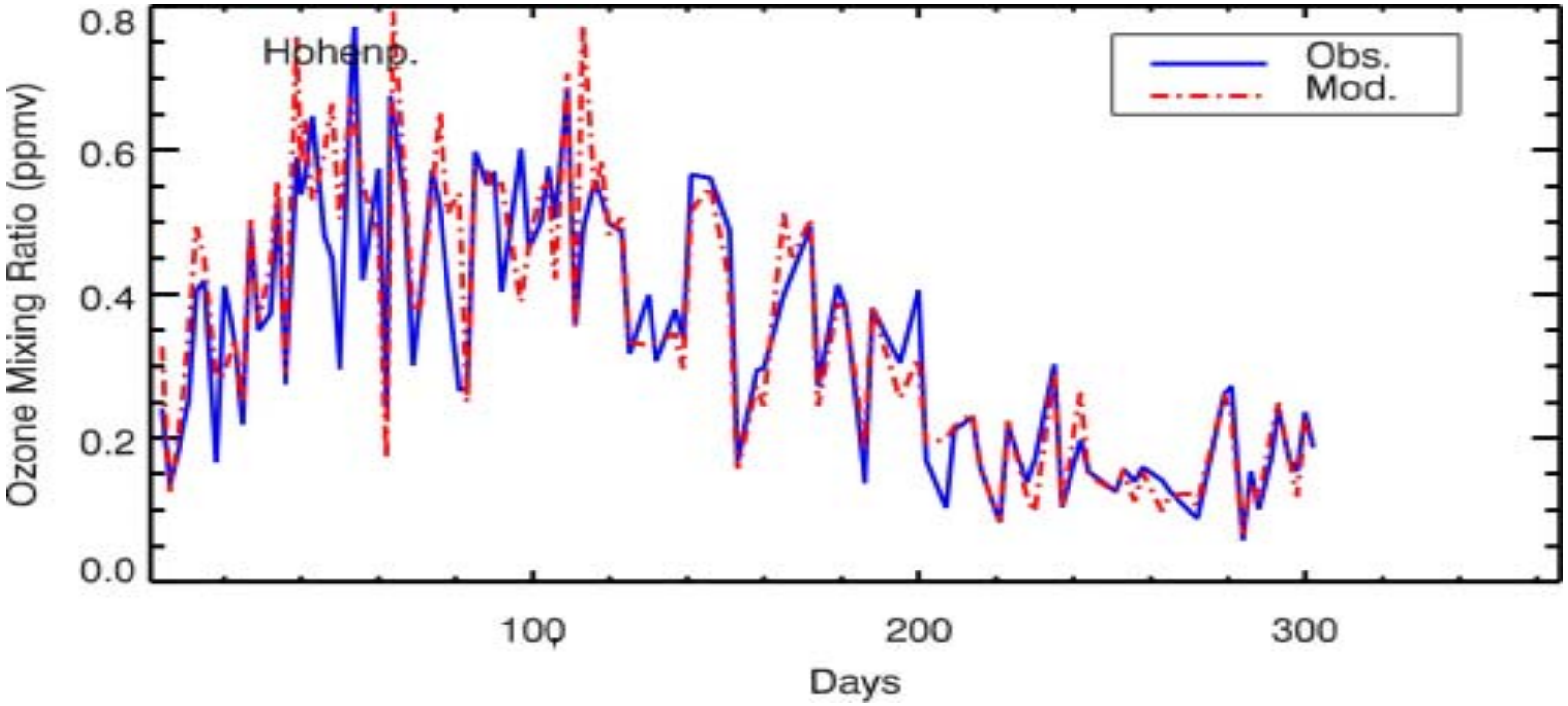
ln(O_3) = 0.2600PV - 2.9925
R = 0.90

Ozone from sonde observations vs ozone from monthly PV-O_3 correlations on 345 K at Payerne in 1999



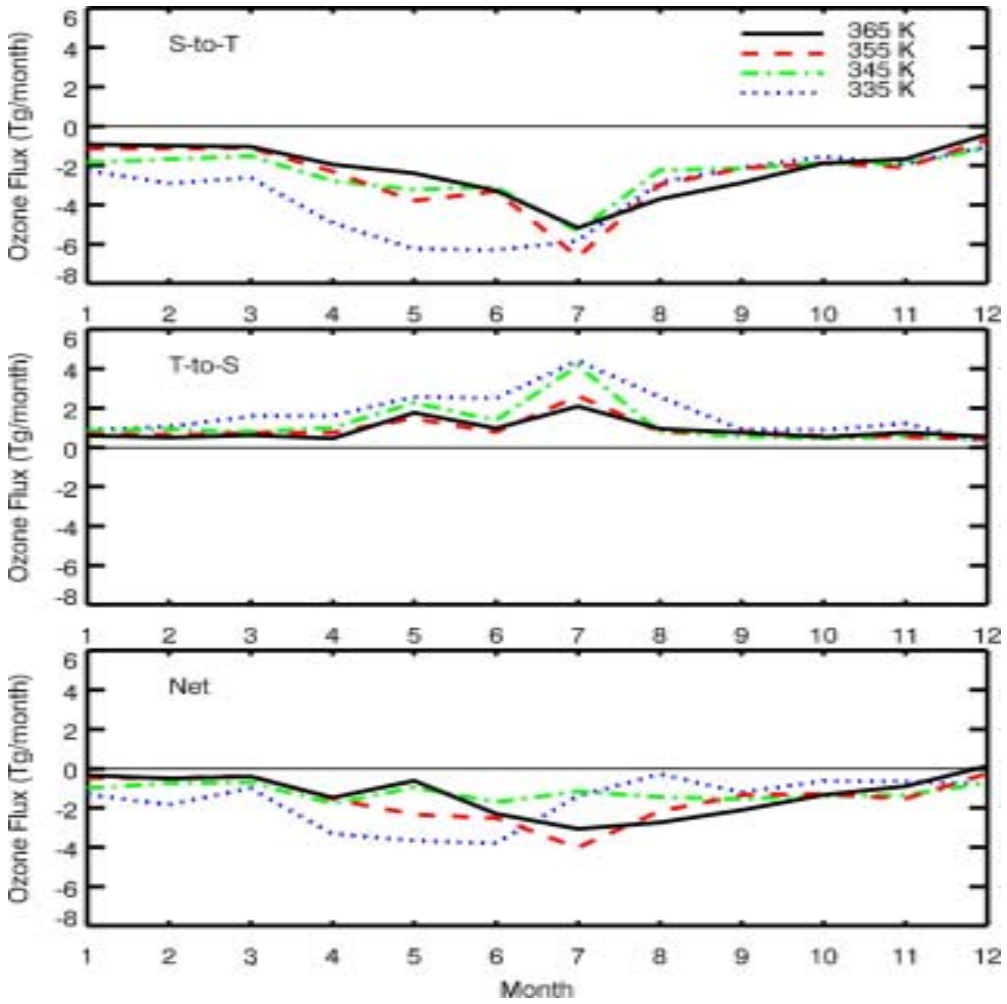
std of the differences = 0.08 ppmv;
R = 0.90

Ozone from sonde observations *vs* ozone from monthly PV-O_3 correlations on 345 K at Hohenp. in 1999



std of the differences = 0.08 ppmv;
R = 0.90

Estimated monthly isentropic cross-tropopause ozone fluxes in the NH in 1999 from the calculations of contour advection

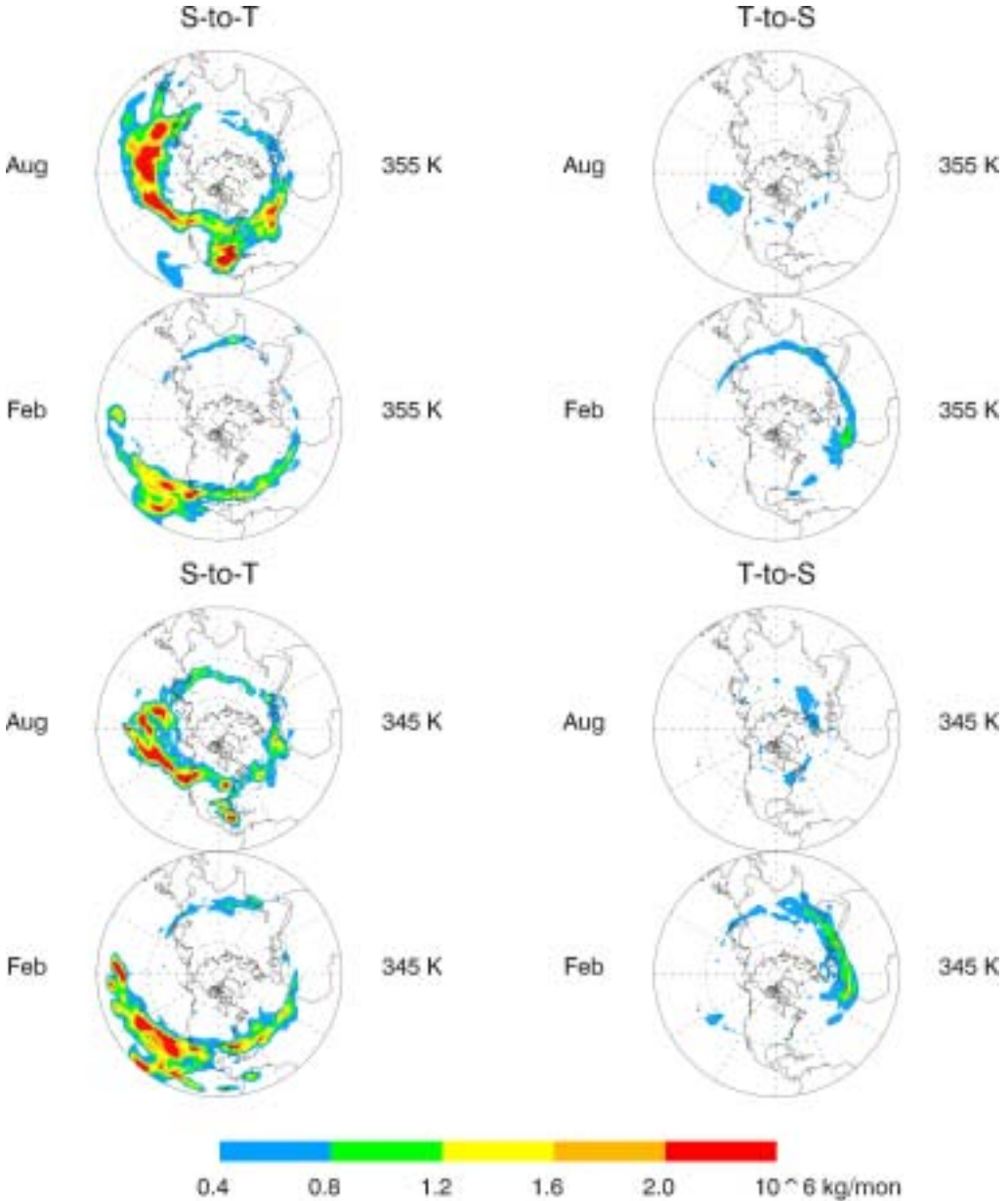


1 Tg = 10^9 kg;

Negative fluxes are from S-to-T;

Positive fluxes are from T-to-S.

Geographical distributions of the estimated monthly ozone fluxes



Estimated annual isentropic cross-tropopause ozone fluxes (in 10^9 kg/yr) in the NH for the years 1990 and 1999

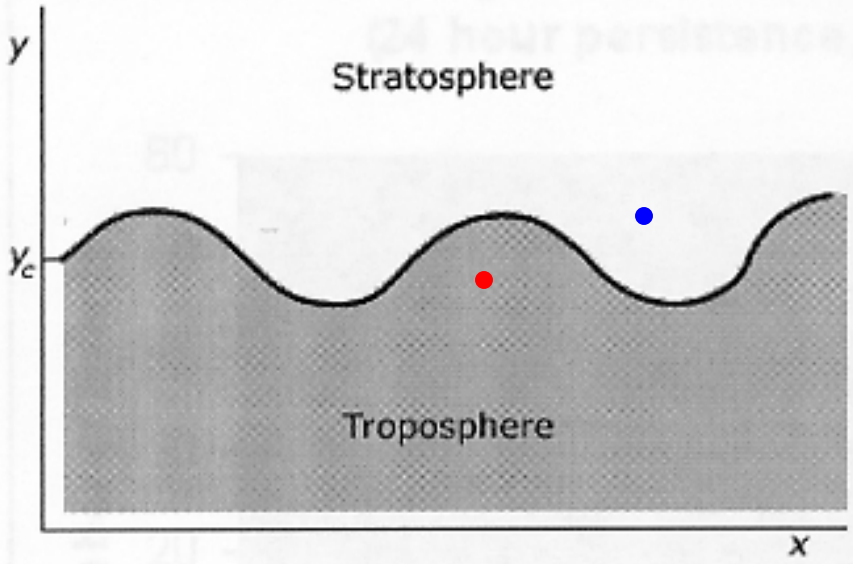
	S-to-T		T-to-S		Net	
	1990	1999	1990	1999	1990	1999
365 K	-22.2	-26.2	10.8	10.6	-11.4	-15.6
355 K	-22.6	-29.1	8.9	11.0	-13.7	-18.1
345 K	-23.8	-28.6	13.4	14.2	-10.4	-14.4
335 K	-31.4	-40.3	21.1	20.6	-10.3	-19.7
Subtotal	-100	-124.2	54.2	56.4	-45.8	-67.8

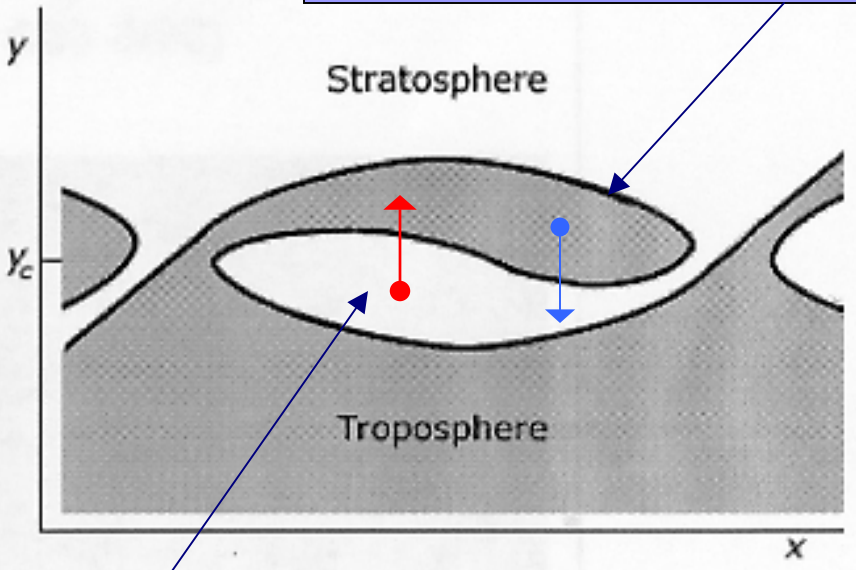
1990: GEOS-1
1999: GEOS-3

NOTE: The average value of the estimated total (both isentropic and diabatic) S-to-T ozone flux in the NH is ~400×10^9 kg/yr by other studies.

Schematic of Rossby Wave Breaking (RWB)

T-to-S breaking: 1. AND 2.
1. Local PV $\leqslant$ 3 PVU
2. PV within 10^o latitude southward becomes $\geqslant$ 4 PVU



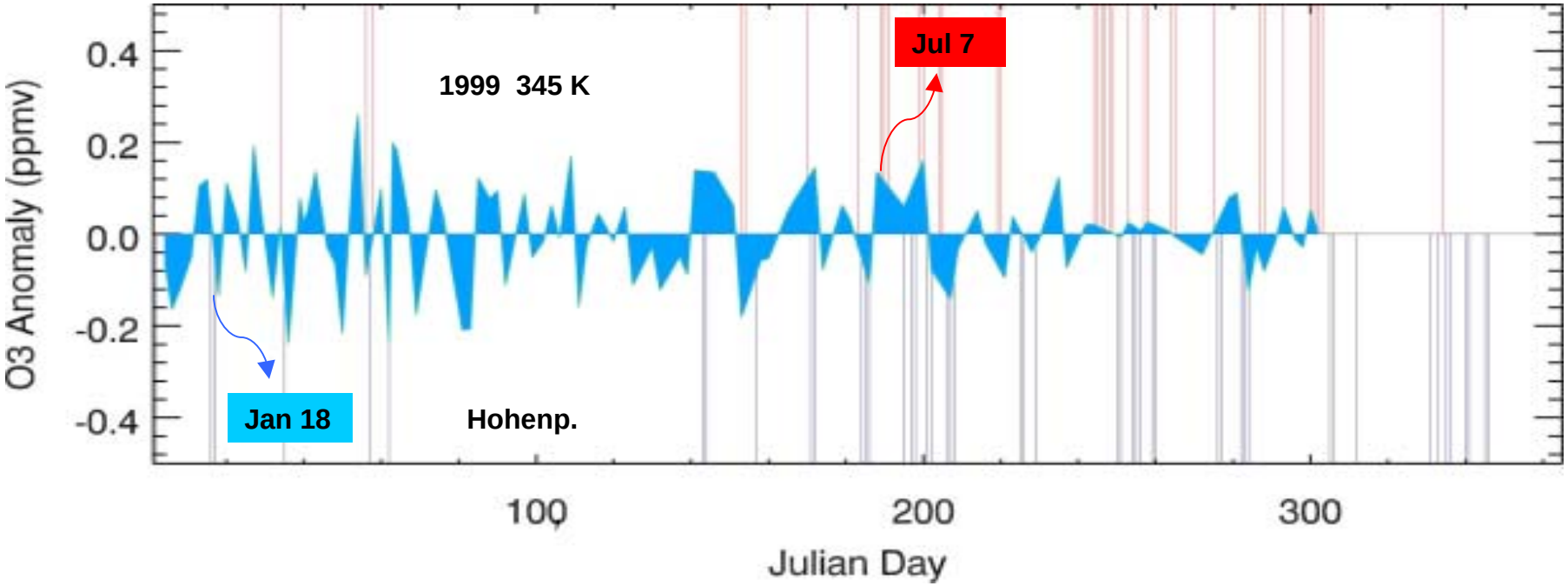


[From J. Wright, 2003]

Tropopause (thick line): = 3.5 PVU
Strats. (un-shaded area): $\geqslant$ 4 PVU
Trops. (shaded area): $\leqslant$ 3 PVU

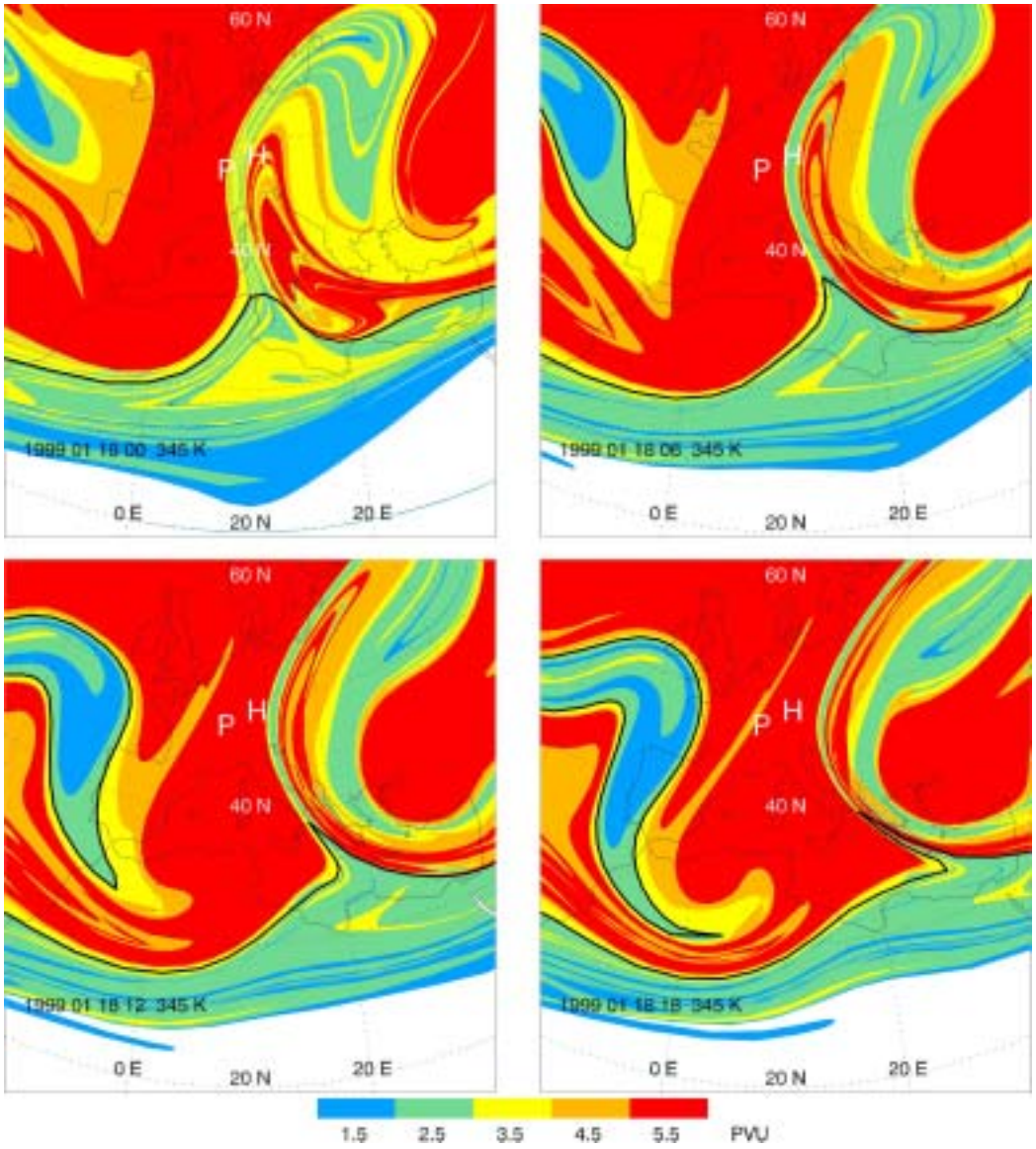
S-to-T breaking: 1. AND 2.
1. Local PV $\geqslant$ 4 PVU
2. PV within 10^o latitude northward becomes $\leqslant$3 PVU

Possible influence of Rossby wave breaking on ozone changes

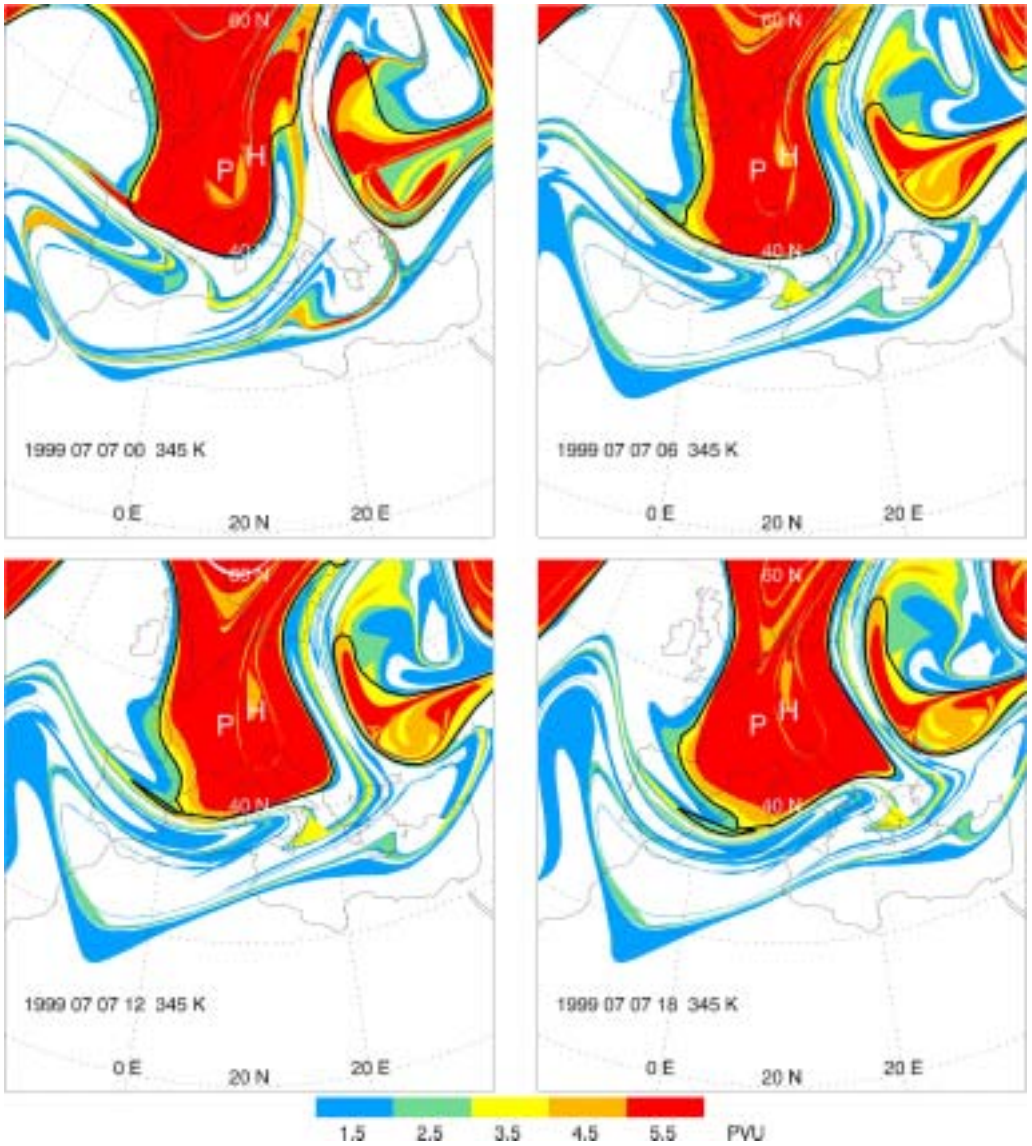


Blue shaded area: ozone anomalies from the sonde observations
Red stripes: occurrences of S-to-T RWB based on the latitudinal PV gradients
Blue stripes: occurrences of T-to-S RWB

A case of T-to-S breaking around Hohenp. on Jan 18, 1999

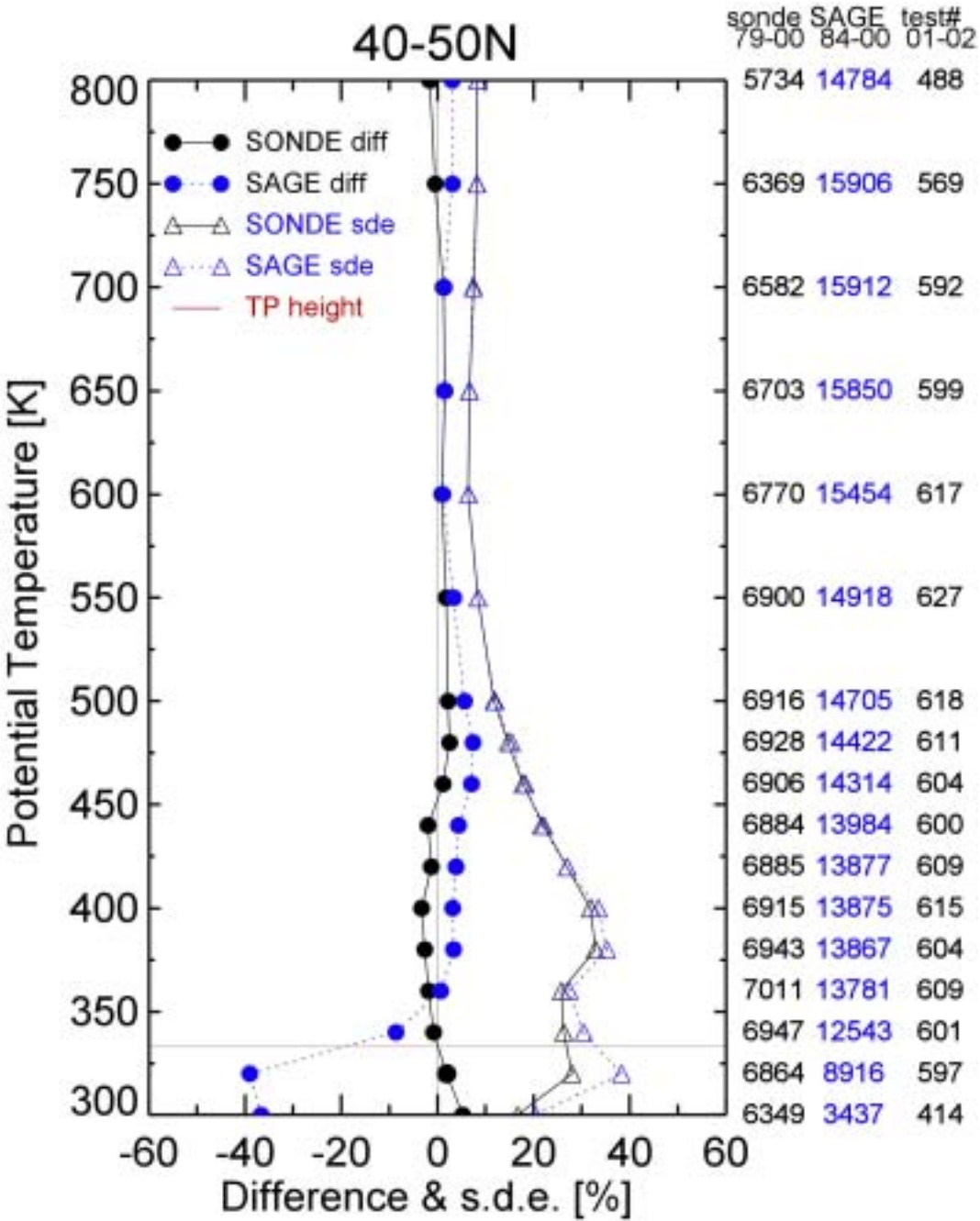


A case of S-to-T breaking around Hohenp. on July 7, 1999



Conclusions

- Isentropic S-to-T exchange is largest in summer.
- It is related to wave breaking for which a spatial distribution of its occurrence can be found (e.g. the Eastern Pacific and the Atlantic oceans).
- Isentropic transport makes a relative small contribution (~10%) to S-to-T total exchange estimates for ozone; it could however be locally important.
- Contour advection and PV mapping is useful for validating and interpreting solar occultation satellite measurements especially near transport barriers. Assimilation models with increased spatial resolution may add precision to the process.


40-50N
sonde SAGE test#
79-00 84-00 01-02
5734 14784 488
6369 15906 569
6582 15912 592
6703 15850 599
6770 15454 617
6900 14918 627
6916 14705 618
6928 14422 611
6906 14314 604
6884 13984 600
6885 13877 609
6915 13875 615
6943 13867 604
7011 13781 609
6947 12543 601
6864 8916 597
6349 3437 414
SONDE diff
SAGE diff
SONDE sde
SAGE sde
TP height
Potential Temperature [K]
800
750
700
650
600
550
500
450
400
350
300
-60 -40 -20 0 20 40 60
Difference & s.d.e. [%]

Evidence for Slowdown in Stratospheric Ozone Loss

M. J. Newchurch[1], Eun-Su Yang[1,2], D. M. Cunnold[3], Gregory C. Reinsel[4], and J. M. Zawodny[5]

1 Atmospheric Science Department, University of Alabama in Huntsville
2 Now at the Georgia Institute of Technology, Atlanta, Georgia
3 Georgia Institute of Technology, Atlanta, Georgia
4 Department of Statistics, University of Wisconsin, Madison
5 NASA Langley Research Center

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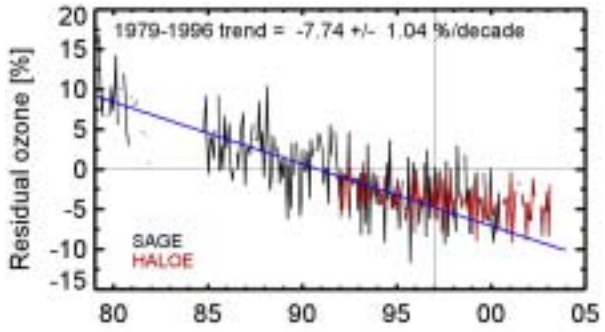
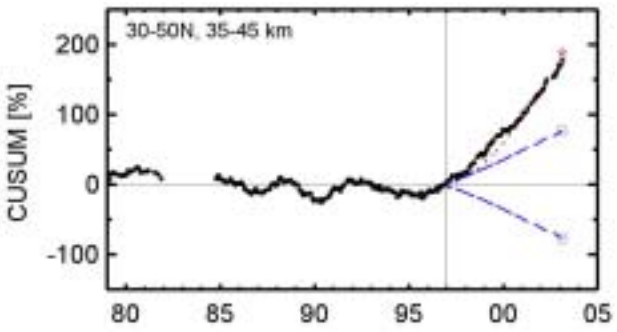
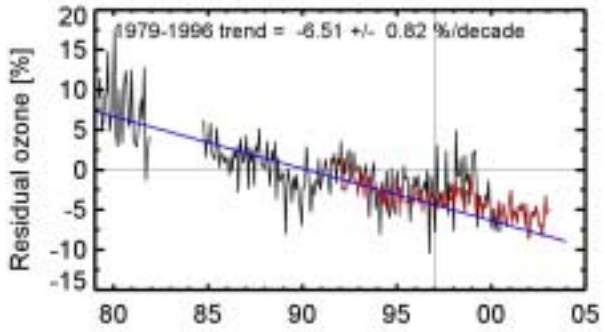
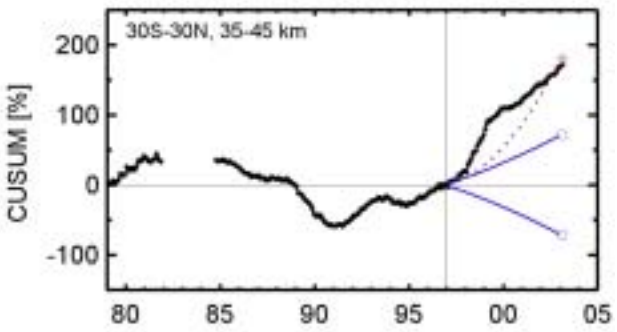
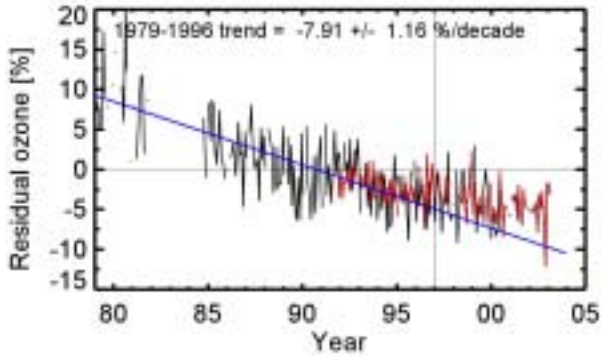
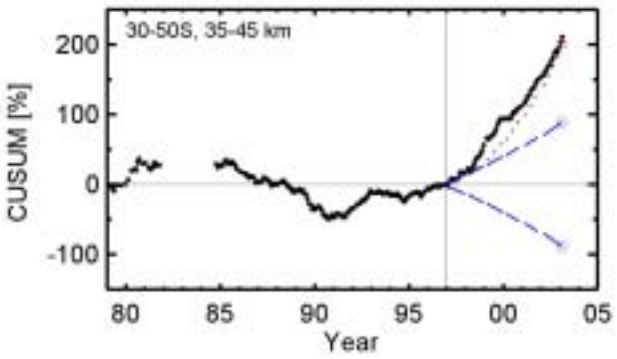

1979-1996 trend = -7.74 +/- 1.04 %/decade
Residual ozone [%]
SAGE
HALOE
20
15
10
5
0
-5
-10
-15
80
85
90
95
00
05


30-50N, 35-45 km
CUSUM [%]
200
100
0
-100
80
85
90
95
00
05


1979-1996 trend = -6.51 +/- 0.82 %/decade
Residual ozone [%]
20
15
10
5
0
-5
-10
-15
80
85
90
95
00
05


30S-30N, 35-45 km
CUSUM [%]
200
100
0
-100
80
85
90
95
00
05


1979-1996 trend = -7.91 +/- 1.16 %/decade
Residual ozone [%]
20
15
10
5
0
-5
-10
-15
80
85
90
95
00
05
Year


30-50S, 35-45 km
CUSUM [%]
200
100
0
-100
80
85
90
95
00
05
Year